Technology for disabilities

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Rory Cooper, an expert in wheelchair design, talked to Ron Davis about his research, his own disability, and new advances in assistive technology

Rory Cooper was 20 years old at the time, stationed with the US army in Germany, riding his bicycle past a bus stop. A bus sideswiped him, pushing him into oncoming traffic. He collided head on with a truck. "It was quite a miracle that I lived," he remembers. "The left front wheel of the truck ran over my chest and broke most of my ribs, broke my clavicle, and fractured my pelvis. And at one time, I had 18 drainage tubes in me."

Summary points

New technologies are improving the effectiveness of rehabilitation services provided to people with disabilities

These technologies include better wheelchair design, tele-rehabilitation (telemedicine applied to rehabilitation), improved prosthetics, new treatments for bowel and bladder control, and more accessible transportation systems

Computer technology applied to electric powered wheelchairs has allowed independent mobility for people with more severe impairment, such as actor Christopher Reeve

Technology development in rehabilitation has not been problem free; access to new treatments and devices is often limited, and electromagnetic interference has occurred between devices (such as hearing aids and hand held telephones)

Primary care doctors should become more knowledgeable about disabilities and should be comfortable making referrals to physical medicine specialists

Patients with disabilities should be treated with a team approach, including a physical therapist, an occupational therapist, a doctor, and often a rehabilitation nurse and counsellor as well

He also experienced a spinal cord injury, at the T7-T8 level. After two chest operations, spinal surgery, six weeks in intensive care, eight more weeks of hospitalisation, and three weeks of rehabilitation, he was left permanently disabled, requiring a wheelchair for mobility. But, remarkably, one year after his accident, he was "independently functional." Ultimately, he decided to devote his career as an engineer to helping others with serious disabilities to become independently functional.

Cooper enrolled as an engineering student at the California Polytechnic State University at San Luis Obispo, California. At that time there were few models of wheelchairs, all of which were fairly heavy—the standard chrome wheelchairs still seen today, used mostly to push people through airports and hospitals. The first wheelchair he used lasted six weeks before it broke. "I thought there must be a better way, so I started building chairs and did that while going to school."

Much of Cooper's early work focused on the design of racing wheelchairs. Up to that point, he recalled, "people just raced the same wheelchair they used every day." Using lighter materials such as aluminium and titanium instead of steel, and adding other improvements such as carbon fibre wheels, he was one of the first to develop a "complete racing wheelchair"—one without the common components of a standard manual wheelchair.

Cooper raced the wheelchairs he designed, continuing his devotion to athletics. Before his accident, as a member of the army's track and cross country teams, he ran races of 5000 to 10 000 metres. After his accident, he competed internationally in wheelchair racing, and in 1987 he held the world record for the 10 000 metre race. Now, he says, he's a "retired athlete." He does arm cycling to stay fit and competes once a year in the National Veterans Wheelchair Games—"mainly to set a goal for myself each year in trying to stay fit, and to be a role model for newly injured people so they have the opportunity to see that you can go back to work, you can participate in sports, and you can have a full life."

After graduating from college, he began his PhD work at the University of California at Santa Barbara, at first concentrating on robotics and bioengineering. His future career plans at the time were to seek a faculty position in robotics or a job at the National Space and Aeronautics Administration. One of his professors, however, convinced him to focus on rehabilitation. "If people with disabilities aren't willing to work on problems for people with disabilities," he remembered being asked by his professor, "how do you expect the rest of us to solve their problems?"

For his doctoral dissertation, Cooper continued his research on racing wheelchairs—investigating how chair design affects performance and the long term health and fitness of wheelchair users. He learned how body positioning influences performance and why racers elevate their knees: "having their knees closer to their trunk gives them greater trunk stability and better biomechanical leverage for use of the arms, and it doesn't impair pulmonary function." He also found that wheelchair athletes were able to perform at a much higher physiological workload than had been previously thought.

After his PhD work, he started a programme in rehabilitation engineering at California State University, Sacramento, which included the establishment of a training programme in rehabilitation engineering and Olympic training camps for athletes with disabilities. He built laboratories to test the performance and durability of wheelchairs, and to study how to prevent the repetitive strain injuries that commonly occur among wheelchair users.

From there Cooper became chair of the first department of rehabilitation science and technology in the United States, at the University of Pittsburgh. The department, with a complement of 60 faculty and staff members and 25 graduate students, provides training to rehabilitation professionals and suppliers of durable medical equipment, operates a joint centre of rehabilitation research and development with the Department of Veterans Affairs, administers a rehabilitation engineering research centre on wheelchairs, and delivers clinical rehabilitation services through a centre for assistive technology.

New technologies in rehabilitation

Tele-rehabilitation

One of the cutting edge technologies his department is working on is tele-rehabilitation, which is telemedicine applied to rehabilitation. "We believe that rehabilitation should be done using a team approach," he explains, "which would often include a physical therapist, occupational therapist, rehabilitation engineer, and physician working with a patient or client to meet his or her needs." A rehabilitation nurse and counsellor might also be involved. But it is not cost effective to send a full team to a person's home or work site for half a day to make an assessment. So individual members of the team are sent to different sites, with "a unit, like an extended laptop computer, which has interface boards for various instruments to collect data." The unit also has one or two video cameras mounted to it for capturing images of the home. Team members then connect to the internet over telephone lines, allowing communication and exchange of data among them—essentially bringing the entire team to each of the field sites simultaneously.

Cooper's department is developing software to transform the video images into a three dimensional, virtual representation of the person's home. "Eventually, we would like to have a virtualised model of various wheelchairs and other assistive devices so you could see that this wheelchair won't fit through here, or we're going to have to build a ramp here, or it looks like we can mount the environmental controls here, or we need to lower this sink. By having a virtualised picture of the home," he explains, "you could modify it virtually and send it back to the patient in the home, and the occupational therapist could say, 'Here's what we are thinking of doing to your house.'"

Wheelchair design

His own personal research continues to be in the area of wheelchair design. What are the major advances in wheelchairs in the past five years? For manual wheelchairs, Cooper identifies two improvements: firstly, a greater understanding of the ergonomics of the chairs and the interaction between chair and user, resulting in better customisation of the chair to the user, and, secondly, improvement in materials, which has allowed customisation of design while keeping the chairs lightweight and functional.

Prototype of the Independence™ 3000 Ibot™ Transporter going up and down stairs, and curbs

Prototype of the Independence™ 3000 Ibot™ Transporter lifting up user to reach higher objects and have eye-level conversations

For electric powered wheelchairs, the most important advances have come from greater use of microprocessors and computer technology. This has made the wheelchair more reliable and more functional for a wider variety of people with disabilities and has allowed independent mobility for people with more severe impairment. Computer technology also allows wheelchair users to adjust the acceleration, the maximum speed, and the rate of turning. "That has permitted people like Christopher Reeve to be able to drive smoothly with his electric powered wheelchair, whereas someone with a spinal cord injury at that high a level 10 years ago probably would have been in an attendant propelled wheelchair or would have had very limited mobility."

Also noteworthy is the introduction of robotics technologies into electric powered wheelchairs. The most exciting product on the horizon, Cooper says, is the Independence 3000 Ibot Transporter, developed by Johnson and Johnson. The Ibot, which is still in prototype form and not yet commercially available, uses robotics technology to balance on two wheels to allow people to reach higher objects and to have eye level conversations, to drive through sand and gravel, and to climb curbs and stairs (see the manufacturer's website, www.indetech.com, for more information).

Other advances

Besides improved wheelchair design, Cooper cites impressive advances that have occurred in other fields of rehabilitation. In prosthetics, active joints allow people a more natural gait and a greater range of activities. Functional neuromuscular stimulation or functional electrical stimulation for bowel and bladder control, especially implantable central neurostimulators, "are showing amazing promise." Cooper mentions robot assisted therapies used primarily for stroke patients, such as using "force therapies" for patients with one sided neglect—that is, forcing the impaired or neglected side to perform a task by using a robot to help perform the task and to measure progress.

"There has been a lot of progress in how to design accessible transportation systems that are safe for passengers with disabilities and safe for those who transport people with disabilities (such as wheelchair users). In seating, we have a much better understanding of the development of pressure ulcers and the use of computer aided seating or cushion designs for ulcer prevention," Cooper adds.

Case studies

Cooper described in detail how two patients have benefited enormously from advances in rehabilitation and assistive technology—one a celebrity and one a former student. He consulted on the rehabilitation of actor Christopher Reeve, specifically on the home modifications he needed. In 1995 Reeve shattered his C1-C2 vertebrae in a fall from a horse. With regard to his medical treatment, injection of corticosteroids by

emergency medical technicians immediately on suspicion of a spinal cord injury and rapid transportation to a trauma centre, were very helpful. "On the rehab side," Cooper notes, "fantastic things have helped Christopher Reeve that wouldn't have been available to him earlier." Those include a functional neuromuscular stimulation exercise programme for the lower extremities to help maintain some level of cardiovascular fitness. Reeve has received treadmill therapy or passive walking therapy, a new approach to train motor pathways and improve range of motion, perhaps reducing contractures; this uses a harness system with a robotic assistant or physical therapist to help guide the feet. New ventilator technology measures the pressure in Reeve's lungs during inflation, and adjusts the injection of air accordingly, allowing him more freedom in speech. "That's a new technology, and that's why you see Christopher Reeve talk as well as he does during television interviews and other public appearances." He is also using electrical stimulation to strengthen his diaphragm and respiratory musculature. He benefits from advanced wheelchair technology, especially in the seating, allowing him to drive his chair effectively in many environments.

"Fifteen years ago the life expectancy of people with an injury like Christopher Reeve's was on the order of months rather than years," Cooper notes. "If they were able to survive, it's very likely they would have been in a nursing home or home care facility. Reeve's injury came at a time when there were tremendous improvements in rehabilitation technology and in medicine related to disability and spinal cord injuries. He has been able to bring out in the public eye that there has been important work in this area, and that significant progress has been made." Remarkably, Reeve has resumed his successful film career, narrating an Emmy Award winning HBO (Home Box Office) documentary about disabled people, hosting a Canadian documentary about spinal cord injury, acting in the CBS television movie *A Step Toward Tomorrow* in 1996, and in the same year directing the critically acclaimed HBO film *In the Gloaming* (starring Glenn Close).

There are many more success stories, of course, among the less famous. Cooper remembers one of his former students, who was severely disabled by cerebral palsy. He had difficulty operating his electric powered wheelchair, so he had limited independence. He could speak, but his speech was very hard to understand and he had a limited vocabulary. However, he was reassessed five years ago and was given a new wheelchair, a new communication system, a customised seating system, and new environmental control. An augmentative communication device allowed him to use a head stick to generate computer synthesised speech. "The benefit was amazing," Cooper noted. "He went from needing full time assistance to requiring only a few hours of assistance in the morning and evening." Eventually, he was communicating by email with professors and fellow students, writing computer software for his master's thesis, and giving presentations at national and international conferences.

Rory Cooper

"That type of person was considered unemployable 10-15 years ago, and now technology has broken through to a point where people with severe disabilities, such as severe cerebral palsy, can not only get a good education and a job but can actually become research leaders in the future."

Problems with new technologies

Electromagnetic interference

One unanticipated problem from new technology in rehabilitation was electromagnetic interference between devices. For example, hand held telephones and hand held radios can cause some electric powered wheelchairs to respond. "Unfortunately, the telephone and radio need to transmit a signal. One approach," Cooper explained, "is to weaken the signal they transmit and to increase the receivers' power and effectiveness. But the electric powered wheelchair also needed to be modified to reduce its responsiveness to electromagnetic interference." Another vexing challenge is to prevent electromagnetic interference of hearing aids from hand held phones placed against the ear. Cooper has worked with the International Standards Organisation to address these incompatibility problems.

Access

Another problem with new technology in rehabilitation is the need to increase access to it. New treatments and devices may be costly, and health insurance payment for them is often limited. "In countries such as the UK the national healthcare system does a very good job of evaluating products but doesn't do a very good job of paying for products," Cooper noted. "There is still heavy reliance in the UK on charities for the purchase of assistive devices and for research on assistive technology." In the United States coverage through the Medicare programme (for elderly and disabled people) is quite poor, but private health insurance has better benefits for assistive technology, and federal law requires local school districts to provide assistive devices and rehabilitation services for children with disabilities.

The problem of access, not surprisingly, is much greater in developing countries, and charitable efforts to export technology to needy countries have failed in the past because of poor infrastructure. Cooper cited as an example the donation of thousands of unused wheelchairs from the United States to other countries, where they became unrepairable in six to nine months. Certain environments (such as unpaved roads) increase the wear and tear on the equipment, and the resources needed for repair and the clinical services needed for assessment and fitting may be lacking. "People might have been bedridden before, but at least they were being cared for," Cooper explained. "Now you put them in a wheelchair without a cushion, and they develop pressure sores, which they might actually die from. We need to train people to develop and maintain appropriate technology locally."

The role of doctors

How can doctors help? "Primary care doctors," according to Cooper, "should become more knowledgeable about various disabilities because common problems in the general population may be masked by a disability." Also, they should feel comfortable making referrals to a good physiatrist. "Physical medicine and rehabilitation doctors, particularly in the United States, should know that disability is a complex medical issue that has many dimensions—social, psychological, and medical. They need to be aware that there are experts in rehabilitation engineering, and they should rely heavily on them. The best way to treat their patients with disabilities is to use a team approach, relying on consultations with people from various disciplines in the rehabilitation professions as well as the disabled persons themselves." Cooper recommends that physiatrists should be primary care doctors for people with disabilities. A disabled person with diabetes, he notes, will probably need more services for

his disability than for his diabetes; therefore, the physiatrist should be the primary carer, who brings in the family doctor, internist, or other specialist as needed.

The future

What will the state of rehabilitation and assistive technology be in 10-15 years, according to Cooper's crystal ball? "I think we'll have a much reduced rate of secondary disability among people with disabilities. For wheelchair users, for example, we will have made significant progress in reducing the occurrence of pressure sores, carpal tunnel syndrome, rotator cuff tendinitis, rotator cuff tears, and spinal and pelvic deformities.

"I'm hopeful we'll see much broader proliferation of assistive technology worldwide. I hope the economies of developing countries will improve so they can pay greater attention to people with disabilities, with assistance from organisations like the United Nations. The work to help victims of land mines is focusing attention on that need.

"There will be a much stronger scientific foundation for rehabilitation medicine in 10-15 years. We'll have a much greater understanding of the effectiveness of the different technologies used. There will be a continued proliferation of computer and robotics technologies, which will be used in therapy to track outcomes and demonstrate functional improvements in people with disabilities."